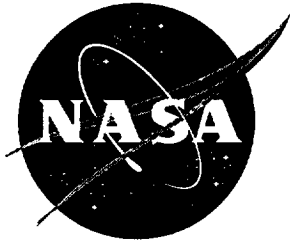


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# AOPA Survey Summary of AGATE Concepts Demonstration October 17-19, 1996

## *Volume I - Basic Report*

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## **Abstract**

An AGATE Concepts Demonstration was conducted at the Annual Aircraft Owners and Pilots Association (AOPA) Convention in 1996. The demonstration consisted of an interactive simulation of a single-pilot, single-engine aircraft in which the participant took off, flew a brief enroute segment and then flew a Global Positioning System (GPS) approach and landing. The participant was provided an advanced “pathway-in-the-sky” presentation on both a head-up display and a head-down display to follow throughout the flight. A single lever power control and display concept was also provided for control of the engine throughout the flight. A second head-down, multifunction display in the instrument panel provided a moving map display for navigation purposes and monitoring of the status of the aircraft’s systems. An estimated 352 people observed or participated in the demonstration, and 144 surveys were collected. The pilot ratings of the participants ranged from student to Air Transport Rating with an average of 1850 hours total flight time. The performance of the participants was surprisingly good, considering the minimal training in a completely new system concept. The overwhelming response was that technologies that simplify piloting tasks are enthusiastically welcomed by pilots of all experience levels. The increase in situation awareness and reduction in pilot workload were universally accepted and lauded as steps in the right direction.



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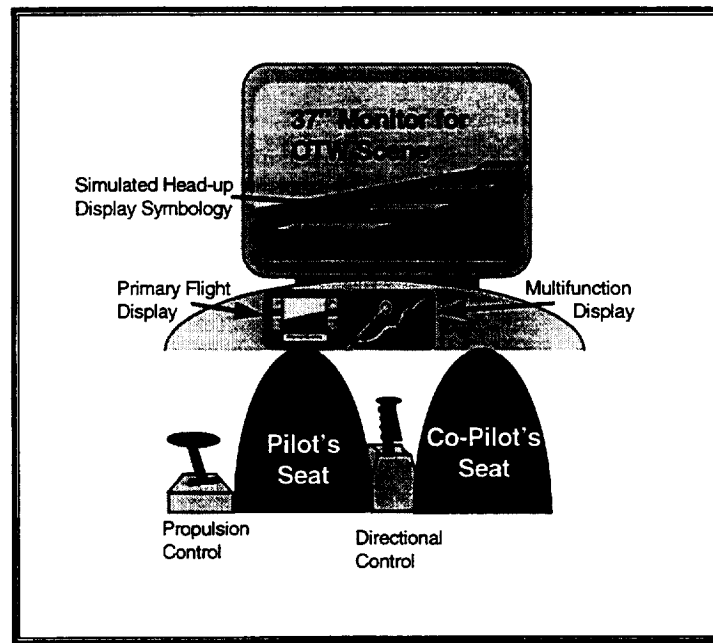
**\* Published under separate cover as NASA CR-201713, Volume II**



**Survey Summary  
of  
AGATE Concepts Demonstration  
At Annual AOPA Convention  
October 17-19, 1996**

**Evaluation of Pilot Survey Data**

The AGATE Concept Demonstrator as depicted below was displayed at the Annual Aircraft Owners and Pilots Association (AOPA) Convention in 1996. An estimated 352 people observed or participated in the demonstration and 144 surveys were collected. The pilot ratings of those individuals that answered questions concerning their qualifications ranged from student to ATP with an average 1850 total flight hours. Overall the response as to the value of the concepts demonstrated was overwhelmingly positive.



**Concept Demonstrator Configuration**

Performance of those who "flew" the concepts demonstration was surprisingly good especially in the light of the fact that the participants had virtually no training in this type of flight presentation. The participants who had the most trouble seemed to be high time pilots unable or unwilling to change the basic flight procedures that were part of their normal flight routine. Again, this is not surprising considering the participants had virtually no prior experience or training with this type of display environment.

Only 30 participants recorded responses to at least one question that were not positive. The composition of the group making negative comments ranged through all pilot ratings and

from pilots with 200 to 16,000 total flight hours with an average of 2160 total flight hours. Most of the negative comments were directed at the concept of a standardized single GPS approach procedure (most did not believe it possible) and the Single Lever Power Control. The responses indicated a likelihood that the nature of the concepts was not clearly understood by many of those that responded negatively.

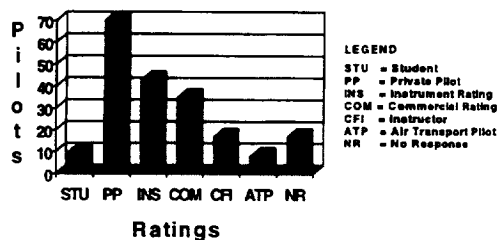
Balancing this group, was another group of 30 pilots with more than 1000 hours total flight time who recorded no negative responses. The average flight time of this group was 5000 total flight hours ranging from 1,000 to 20,000 total flight hours.

The AGATE demonstration pilots showing the concepts to the AOPA participants observed that overall performance of the participants was surprisingly good considering the minimal training in a completely new system. The overwhelming response was that technologies that simplify piloting tasks are enthusiastically welcomed by pilots of all experience levels. The increase in situation awareness and reduction in pilot workload were universally accepted and lauded as definite steps in the right direction. The popular choice is simplification.

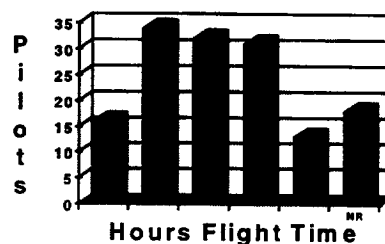
## Significant Characteristics of AOPA Convention Concepts Demonstration Participants

Of the pilots that answered the questions on the survey form:

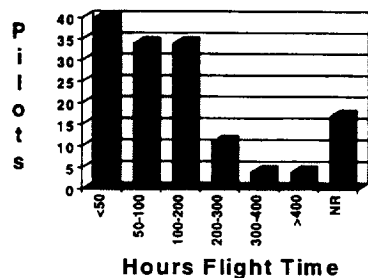
### 30% were instrument rated



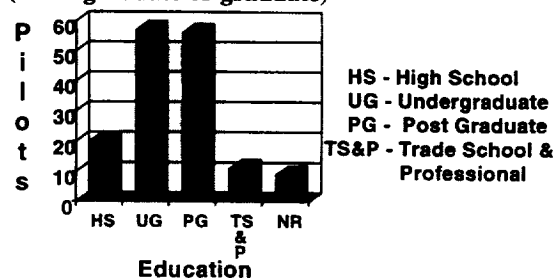
### 64% had less than 1000 hrs flight time



### 57% flew less than 100 hrs in the last year

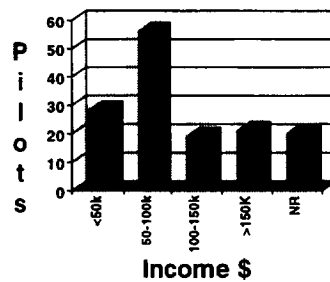


### 76% had college degrees (undergraduate or graduate)





**68% Make \$100K or less, 45% make 50K to \$100K, 17% make over \$150K**



## **Pilot Responses to AGATE Technology Questions**

Of the 144 respondents who filled out the survey after flying or observing:

The range of experience was from very low time student pilots to extremely high time Air Transports Pilots with up to 20,000 hours of total flight time.

35% of the respondents chose not to answer the first question. This question asked whether or not the display concepts shown increased situation awareness and asked the pilot to explain why or why not. Of the respondents answering the questions 97% were positive. This reluctance to answer the first questions may have been due to its "essay" format.

30 had comments or answers that were other than positive (maybe, don't know, or negative). Of this group, pilot ratings ranged from very low time pilots (100 hrs) to very high time Air Transport Pilots (16,000) with the average flight time at 2,164 hrs.

- 23 individuals had a single negative response
- 6 individuals with negative responses had two areas of negative response
- 1 individual had 3 negative comments

The count of comments in areas where pilots recorded other than positive comments were as follows:

- 15 for the concept of a single GPS approach procedure. Most saying they did not believe it could be done
- 12 recorded that they did not believe the SLPC would be an increase in value
- 5 did not believe the "highway in the sky" presentation made navigation easier
- 3 did not feel the head-up display represented an increase in value
- 3 did not feel the display in the concept demonstrator improved situation awareness
- 114 pilots recorded only positive comments

30 high time pilots (more than 1000 hrs total flight time) ranging from 1,000 to 20,000 hrs total flight time (average of 5001 hrs) had only positive comments recorded.

## Comments of Demonstration Respondents

With regard to situation awareness, typical pilot comments were:

- “Inclusion of highway and terrain features give exact image of position with respect to desired path. No mental computation necessary.”
- “The display let you just ‘point and fly’. The pilot doesn’t have to think about each individual task. The system does all the ‘ciphering’ and frees the pilot to just follow a preplanned route.”
- “The plan view on MFD, along with the 3-D PFD eliminate any SA problem.”
- “Obviously a picture is worth a thousand instruments!”

Pilot concerns were generally about fixation and the compelling nature of the visual “highway” display.

With regard to the value of a head-up display, typical pilot comments were:

- “HUD keeps the pilot’s eyes out of the airplane where they belong.”
- “Dramatic workload reduction. Particularly on approach.”
- “Less error and more comfort flying.”
- “Requires less head movement, less scanning and lightens work load.”

Pilot concerns again were about obscuration of outside cues and fixation on the display elements.

With regard to the Single Lever Power Control, typical pilot comments were:

- “Simple is best”
- “Reduced pilot workload”
- “More efficient engine management”
- “Easy to use”

Pilot concerns were about system complexity and increased maintenance costs with occasional comments regarding a perceived reduction in pilot control over aircraft performance.

With regard to the Single Lever Power payback time after purchase:

The average of the time selected for payback of initial investment in SLPC technology (for those who selected less than 10 years) is 4.17 years.

With regard to the desirability of a single GPS approach procedure that looks essentially the same to the pilot at every airport:

- “It would keep things simple”
- “Obvious - very easy to learn. 1 universal “approach” rather than ILS, NDB, VOR...”
- “Standardizing makes it easier to learn”
- “Reduces the chance of pilot error”

Pilot concerns were primarily skepticism that a “single approach” would be able to meet all terrain or airport conditions. This response probably reflects a misunderstanding of the concept of a standardized “procedure” that “looks essentially the same” versus an identical approach for every airport. This concept should be better explained if it is to be included in future demonstrations.

With regard to the highway-in-the-sky, typical pilot comments were:

- “Much more intuitive than traditional instruments.”
- “People can relate to ‘lanes’ from driving. So, adoption and time to proficiency would be reduced.”
- “Most of us only have a dim view without GPS of where we are. The highway would completely resolve this.”
- “Great feedback on every axis, much like driving.”
- “Navigation becomes a ‘No-brainer’.”

Pilot concerns were about boredom and fixation on the highway display, and the need for cues for “off highway” situations.

With regard to which concepts offered the most value, typical pilot comments were evenly distributed about many of the concept demonstrator features. Items repeatedly mentioned included the head-up display, the highway-in-the-sky format, the SLPC and the simplicity of the unified concept.

With regard to which concepts offered the least value, typical pilot comments were evenly distributed about many of the concept demonstrator features. Items repeatedly mentioned included the SLPC, the lack of rudder pedals and concern over the possibility of computer/electrical failure and backup modes both for pilot and aircraft.

## **Comments of Demonstration Pilots**

Dr. Alan Stokes, General Aviation pilot, Ph.D., Human Factors, Florida Institute of Technology:

“Overall a very successful event. An excellent platform for developing hypotheses and studying performance. It is difficult to see how ideas like this could be demonstrated without a tool like this or how a system like this could be developed without a platform for testing pilot and system performance.”

“Very worthwhile and eye-opening...saw things that I wouldn’t have otherwise guessed. Flying this way is definitely a different way of doing business.”

“There is something very different and psychologically compelling about the path in the sky that causes pilots, even highly trained pilots, to react and sometimes overcorrect.... There was an interesting difference between objective performance (generally right on track) and subjective performance (a feeling that the pilot was not doing as well as he should have).”

“Very successful in demonstrating the concepts with a wealth of opportunities for gathering information relevant to the AGATE program.”

Mr. Cliff Brust, General Aviation pilot, Engineer at Advanced Creations, Inc., (Flight Systems and Integrated Avionics):

“Overall the demonstration went really well. Even the most die hard, old paradigm pilots like the approach mode performance. Training was nil, performance was very high and very persuasive. Concerns were over the “hypnotic” and compelling nature of the “highway in the sky”. These things need to be studied.”

Mr. R. J. Stewart, General Aviation pilot, Global Aircraft Corp.:

“Probably the best lesson to be learned from the concept demonstrator at the AOPA Convention was that a display can be designed that is appealing to the untrained public and avoid the extensive skill requirements that are currently needed to become a pilot... I think that one of the focuses of the demonstrator ought to be to show that whatever concepts we come up with are easier for the general public to deal with, as opposed to our current crop of pilots. Enough data should be collected in controlled experiments to show that these findings are technically correct. If we accomplish this, then we are performing the true intent of the AGATE mission, by making flying easier to learn, and opening up flying to the general public...”

“I think that the concept demonstrator, as we are envisioning its utilization...can be a cornerstone of the AGATE effort.”

Mr. Malcolm Burgess, General Aviation pilot, Program Director for Systems Engineering, Research Triangle Institute:

“The interest of the participants was clearly evident in innovative new concepts for simplifying the task of IMS flight operations. There are many good ideas not yet fully investigated - the excitement and performance of the participants in this demonstration is clear evidence that we must pursue simpler, more cost effective, and more intuitive interfaces between the pilot, the aircraft and the infrastructure in which we wish to fly.”

Mr. Timothy Sestak, General Aviation pilot, Senior Program Engineer, Research Triangle Institute:

“The performance of the participants was surprisingly good considering their entire training scenario was 10-15 minutes of verbal instruction, half of which was AGATE program information and theory. The overall concept of simplification and reduction in pilot workload was universally lauded as the “right stuff”. Most objections were more a lack of belief in whether or not the capabilities presented are technically achievable in the foreseeable future than a disagreement with the basic premise presented. This clearly demonstrated the efficacy of the concept demonstrator and tools like this, not just for advocacy purposes but in determining what the “customer” really wants and needs.”



## **APPENDIX A**

### **AGATE Concepts Demonstration Questionnaire**





# AGATE Concept Demonstrator Survey

We would appreciate your feedback about the demonstration you have just seen. Where the questions ask about value, we realize that each individual may have a different basis for value. Time, Cost, Performance, Ease of Use, and Safety are some of the ways by which we measure value. Please state which value factors you consider most important in your answer. Use space on the back of the paper as necessary.

Did you fly the concept demonstrator ☐

or observe? ☐

The AGATE Concept Demonstrator shows use of possible new display concepts intended to improve the pilot's awareness of his or her position and situation. Do you feel the display concepts shown would increase your situation awareness? Why or why not?

The AGATE Concept Demonstrator shows the concept of a "Head-Up" Display used with other instrument displays.

Would the head-up display represent for you:

An increase in value over present general aviation aircraft display systems?: ☐

No increase in value over present general aviation aircraft display systems?: ☐

A decrease in value over present general aviation aircraft display systems?: ☐

Why do you believe this?

The single lever power control would allow a pilot to operate the engine at maximum efficiency while reducing operating and maintenance expense.

Would the single lever power control represent for you-

An increase in value over present general aviation aircraft systems?: ☐

No increase in value over present general aviation aircraft systems?: ☐

A decrease in value over present general aviation aircraft systems?: ☐

Why do you believe this?

If the single lever power control made the initial purchase of an aircraft more expensive, what would you accept as the maximum time for the savings in operation and maintenance to pay back the added initial purchase expense?

1 year ☐

5 years ☐

2 years ☐

7 years ☐

3 years ☐

10 years ☐

longer ☐

Do you like the concept of a single GPS approach procedure that looks essentially the same to the pilot at every airport? YES ☐ NO ☐

Why?

Would a graphic "highway in the sky" display presentation make navigation easier? YES ☐ NO ☐

Why?

What concept(s) in the AGATE Demonstration here do you believe offers the most value to you as a general aviation pilot? Why?

What concept(s) in the AGATE Demonstration here do you believe represents the least value to you as a general aviation pilot? Why?

Please provide the optional information on the back of this form.

Please tell us something about yourself so that we may better understand the needs of the general aviation pilot.

What Ratings do you currently hold?:

Private pilot ☐

Instrument ☐

Commercial ☐

CFI ☐

ATP ☐

How many total hours flight time have you logged?:

How many hours flight time did you log in the last year?:

What type aircraft are you currently flying?:

How much formal education have you completed?:

High School: ☐

Undergraduate College Degree: ☐

Post Graduate Degree: ☐

Trade School/professional training: ☐

What is your current profession?:

What is your income level?:

up to \$50,000 per year ☐

\$50,000 to \$100,000 per year ☐

\$100,000 to \$150,000 per year ☐

over \$150,000 per year ☐

Please use this space to tell us anything else you think we should know about your impressions of the AGATE Concept Demonstrator. Thank you for your time!

## **APPENDIX B**

### **AGATE Concepts Demonstration Data Summary**



DATA SUMMARY  
AOPA 1996

81 OBSERVERS                      0.5625  
63 FLYERS                        0.4375  
144 RESPONDENTS

91 INCREASED AWARENESS  
1 NO INCREASED AWARENESS  
1 MAYBE  
1 NOT SURE  
50 NO ANSWER

PAY BACK

9 1 YEAR  
17 2 YEARS  
43 3 YEARS  
42 5 YEARS  
8 7 YEARS  
5 10 YEARS  
5 > 10 YEARS  
15 NO ANSWER

141 INCREASED VALUE WITH HEADUP  
2 NO INCREASE IN VALUE  
1 DECREASE IN VALUE

131 INCREASED VALUE WITH SLPC  
8 NO INCREASE IN VALUE  
4 DECREASE IN VALUE  
1 NO RESPONSE

SINGLE GPS APPROACH CONCEPT

126 YES  
16 NO  
1 Y/N  
1 NO ANSWER

HIGHWAY MAKES NAV EASIER

135 YES  
4 NO  
2 Y/N  
3 NO ANSWER

352 ESTIMATED PARTICIPANTS  
88 ESTIMATED FLYERS  
264 ESTIMATED OBSERVERS

RATINGS HELD

9 STUDENT  
70 PRIVATE PILOT  
43 INSTRUMENT  
35 COMMERCIAL  
17 CFI  
8 ATP  
17 No response

FLIGHT TIME

TOTAL HOURS	LAST YEAR
13 OVER 5000	4 OVER 400
31 1000 TO 5000	4 300 TO 400
32 350 TO 1000	11 200 TO 300
34 100 TO 350	34 100 TO 200
16 LESS THAN 100	34 50 TO 100
18 NO RESPONSE	40 0 TO 50
	17 No Response

EDUCATION

20 HIGH SCHOOL  
57 UGD  
56 PGD  
11 TS/PT  
9 NO ANSWERS

INCOME LEVELS

28 UP TO \$50,000  
56 \$50,000 TO \$100,000  
19 \$100,000 TO \$150,000  
21 OVER \$150,000  
20 NO ANSWERS



## **APPENDIX C**

AGATE Concepts Demonstration Plan





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## **1. SCOPE**

This document identifies and describes the scenario, the requirements and the design of the AGATE Concept Demonstrator (ACD) as it will be configured for the EAA Fly-in in Oshkosh, Wisconsin for 1996. The demonstration concept and scenario are followed by the functional and physical requirements and design.

The ACD is a facility that has been created to demonstrate advanced AGATE concepts in a simulated generic AGATE general aviation aircraft. Its purpose is to demonstrate AGATE program concepts to the public to elicit potential customer/user feedback on the perceived values and benefits of AGATE concepts, and potentially to serve as a market analysis tool. Physically the ACD consists of a mockup of a small aircraft cockpit enclosed in a metal frame covered with dark cloth. The enclosure is large enough to surround the physical cockpit mockup with room for an observation area and all required computer equipment to drive the simulation. The enclosure serves to provide a darkened environment for easy display readability, climate control, and crowd control. The cockpit mockup consists of a cutaway fiberglass shell representing an aircraft fuselage, with two seats in a side by side configuration, an instrument panel with two large Liquid Crystal Displays (LCD) and a single set of aircraft controls. In 1996, the ACD will be used to demonstrate the pilot-vehicle interface for the Single Lever Power Control (SLPC), examples of possible SLPC functions, and concepts for advanced display formats and symbology.

Operation of the ACD will require three people including one operator and two demonstration pilots. The operator will setup and control the physical operation of the computers, controls, display hardware and software from the operator workstation. A demonstration pilot will brief visitors to the concepts demonstrator on the AGATE program, the purpose of the demonstration, the flight scenario in the demonstration, and the concepts illustrated by the demonstration, and will then take the visitors into the concepts demonstrator, and facilitate the demonstration. One visitor will be seated in the concept demonstrator and 3 or 4 other observers will be able to watch from behind the subject pilot's and demo pilot's seats. The demonstration pilot will accompany the visitors until the demonstration ends, answer visitor questions, explain the concepts displayed, and escort the visitors from the

concept demonstrator before the next demonstration pilot brings in the next group. To maximize the throughput, the visitor briefing will be conducted at the briefing station in parallel with the flight demonstration inside the mockup, requiring two demonstration pilots at any one time. A video camera inside the enclosure will transmit the OTW scene to a large monitor beside the briefing station to keep the demonstration pilot giving the preflight briefing apprised of the progress of the current demonstration flight and allow other visitors to watch from outside the enclosure.

## **2. DEMONSTRATION SCENARIO**

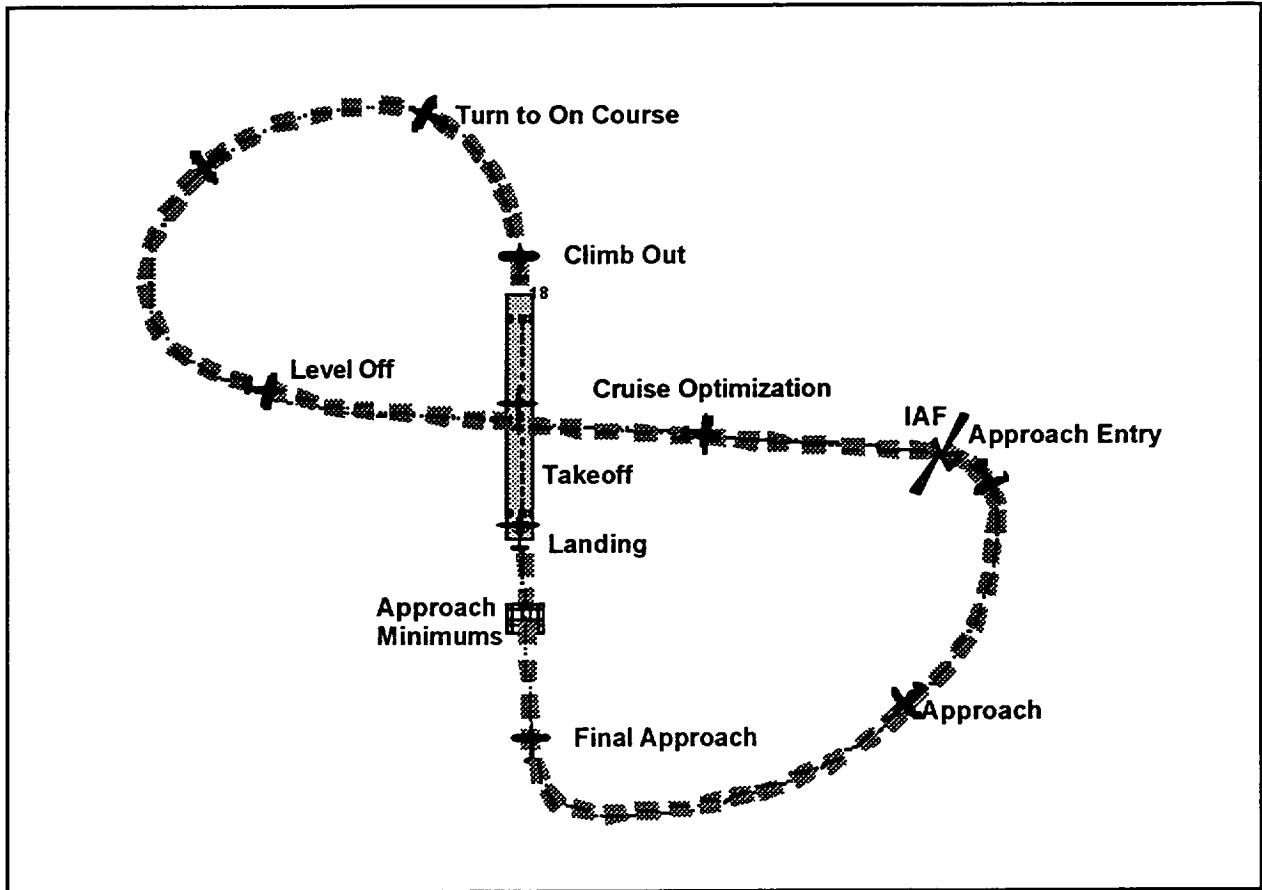
The purpose of the ACD in 1996 is to demonstrate AGATE program concepts highlighting the functions and operation of a Single Lever Power Control (SLPC) and AGATE advanced flight display symbology. The scenario for the demonstration is represented in Figure 1. This "flight plan" will be used by the ACD Operator to guide a visitor through the demonstration. The flight, if flown accordingly, will last approximately 8 minutes. The scenario begins and ends on Denver International Airport's runway 35L. The following abbreviated script outlines the demonstration scenario.

1. Demonstration pilot provides briefing to visitor using two or three large posters affixed to the external wall of the concept demonstrator. Briefing consists of explanation of AGATE program goals, concept demonstrator purpose, SPLC function, advanced display concepts, and operation of the concept demonstrator by the visitors. Demonstration pilot selects one visitor to pilot the concept demonstrator. If there are no visitors capable of operating the concept demonstrator simulation the demonstration pilot will "fly" the demonstration while the visitors watch.
2. Demonstration pilot escorts briefed visitors into the concept demonstrator and assures they are properly seated and that all visitors have an appropriate view of the demonstration.
3. Demonstrator pilot briefs visitors on operation of ACD controls and briefly reviews flight scenario.
4. Operator starts the simulation at demonstrator pilots request. Aircraft is positioned at the approach end of DEN RNWY 25, ready for takeoff.
5. PFD and MFD displays are initially ARNAV conventional display format. At Demonstrator pilots request the display format changes to advanced format and remains in advanced format for duration of the demonstration.
6. MFD indicates aircraft is "Cleared for takeoff".

7. After acknowledging takeoff clearance, Pilot advances SLPC to TAKEOFF detent.
8. Aircraft brakes are released, engine increases power output, aircraft begins to move, pilot controls aircraft down runway centerline.
9. PFD displays rotation prompt at rotation point. Pilot can see progress of aircraft approaching rotation point on PFD. At rotation point, pilot rotates nose to indicated takeoff/climb attitude and aircraft becomes airborne.
10. Departure path appears as "highway in the sky".
11. Aircraft path maintains runway heading climbs to 500 feet AGL altitude at an angle that represents 1500 FPM rate of climb.
12. At 500 feet, PFD prompts Pilot to reduce SLPC to CLIMB detent, and displays the overhead of mission flight plan. Flight path on MFD shows equivalent of left hand standard rate turn at 1300 fpm rate of climb to a heading that will take the aircraft direct to initial approach fix (IAF). Coordinates for IAF are 360° from the center of RNWY 25 at 4.75 statute miles.
13. Pilot reduces SLPC to CLIMB and begins left turn following the displayed flight plan. Aircraft rate of climb reduces to 1300 FPM and performs coordinated turn with respect to Pilot's control input.
14. As left turn is completed to heading needed to proceed direct to IAF heading, path straightens and pilot follows path rolling aircraft to wings level attitude.
15. As the aircraft approaches level-off altitude of 2500 feet AGL, pathway on PFD shows flight path level off on assigned altitude. Sign by "roadside" shows AGL and MSL altitude. Cues appear on the MFD and PFD for leveling off. As pilot lowers nose to follow path, aircraft accelerates toward cruise airspeed.
16. Cruise transition query appears on the MFD for pilot to select Max Range, Max Efficiency, Max Endurance, or "scheduled to arrive at (enter time)" cruise setting. Pilot moves SPLC to highlight desired setting (max. range) and designates his choice by pressing a switch on the SLPC or by depressing a switch while positioning the SPLC in the cruise detent and then releasing the switch. The aircraft system computes appropriate speed and performs accordingly.
17. Pilot flies aircraft over flight path using PFD cues.
18. As aircraft approaches 1 mile (20 seconds) from IAF, the IAF symbol appears ahead on path. IAF is presented in form of visual cue on the flight path. 10 seconds from IAF, symbol turns green in color to indicate the aircraft is cleared for the approach.
19. Pilot maneuvers aircraft along path, past IAF symbol. Path turns right depicting 5 mile arc around runway center point.
20. Pilot flies path at cruise airspeed, arc path descends to 1000' AGL and levels off at 1 mile (20 seconds) prior to turn onto final approach course.
21. 1 mile prior to final approach course turn, PFD and MFD prompt pilot to move SPLC lever to APPROACH setting.

22. PFD and MFD show prompt to place SPLC in APPROACH detent. Aircraft holds predetermined approach speed (this speed below landing gear cycle speed for retractable gear) through descents and level off, without pilot input. Pilot places SPLC in detent, aircraft decelerates and holds 120 knots.
23. Pilot follows approach path in level turn to final approach course, and reaches wings level position, on course just before 4 miles from runway. PFD and MFD show flight path descent. Pilot follows path using aircraft pitch attitude to control aircraft motion just above path. SPLC system maintains 120 knots throughout descent maneuvering.
24. Runway environment icons including runway, runway centerline, approach lights, taxiway turnoffs, significant obstructions and obstacles appear on PFD and MFD. Presentation on PFD is a perspective three-dimensional representation.
25. PFD and MFD give wind indications on final approach course. Large wavy ghost arrow in background of PFD showing relative direction and strength; arrow across flight path on MFD with relative direction, compass direction and wind speed.
26. Pilot follows flight path down to runway. Instrument minimums are indicated on PFD in a similar manner.
27. Pilot flies aircraft down path to flare transition. In flare pilot moves SPLC out of approach detent to reduce power and manually land aircraft. Demo Pilot may request operator to stop or freeze simulation at any point in landing transition.
28. Pilot and observers exit concept demonstrator.
29. Operator resets ACD to takeoff point. Note that the Operator may reset the ACD to the takeoff point at any time during the simulation as required by circumstances.
30. Simulation is reset to initial conditions; on runway, ready for takeoff.
31. New pilot enters and is seated. Simulation is started again.

Figure 1. Demonstration Flight Scenario



### 3. REQUIREMENTS

#### 3.1 GENERAL REQUIREMENTS

1. Concept demonstrator is to be enclosed.
2. Concept demonstrator consists of a cockpit mockup with interactive controls allowing the demonstration to be an interactive flight simulator for the purposes of the demonstration.
3. Two cockpit displays are to be provided, these displays must be capable of demonstrating advanced concept display symbology.
4. An out-the-window (OTW) visual scene is to be provided and to be interactively synchronized with the cockpit mockup controls and cockpit displays so as to allow the concept demonstrator to be "flown" as a simulated aircraft using the cockpit mockup controls.
5. Two or three large posters are to be provided describing AGATE program goals, concept demonstrator purpose and concept demonstrator scenario.

6. An operator will be responsible for hardware and software operation and at least two demonstration pilots are continuously present during ACD operations.
7. The demonstration scenario shall have a planned cycle rate of 4 to 6 demonstrations per hour. A demonstration will consist of an 8-12 minute "preflight briefing," a 1 minute transition from outside the concept demonstrator to inside the concept demonstrator, an 8 minute flight scenario, and a 1 minute exit from the concept demonstrator. The preflight briefing will overlap the flight demo to maximize the number of visitors.
8. The PFD shall provide a perspective presentation of advanced display concepts to include the horizon, significant terrain, key visual landmarks, checkpoints, or obstructions relevant to the flight path, and sufficient control information to permit real time interactive flight simulation and control by the system visitors who have flight experience.
9. The MFD shall provide information for management of aircraft systems and advanced weather and navigation information to demonstrate AGATE concepts.

### **3.2 SPECIFIC SYSTEM REQUIREMENTS**

1. The ACD shall use two ARNAV displays formatted as a Primary Flight Display (PFD) and a Multi-Function Display (MFD) (with necessary associated ARNAV hardware and software).
2. An Operator Control Station (OCS) shall provide the flight modeling and simulation control for the ACD.
3. The OCS shall drive the PFD and MFD displays at a minimum 10 Hz rate.
4. Simulation control at the OCS shall include the ability to reset the aircraft to the beginning of the demonstration scenario.
5. An Out-The-Window (OTW) Visual System shall provide visual scenes for the cockpit demonstration on the 37" Mitsubishi monitor provided in the current concept demonstrator.
6. The OTW Visual System shall maintain a minimum 30 Hz update rate.
7. A single control stick shall provide coordinated control of the pitch, roll, and yaw axes for the simulated aircraft.
8. An SLPC shall provide coordinated control of thrust, propeller pitch (if applicable), and fuel mixture for the simulated aircraft.

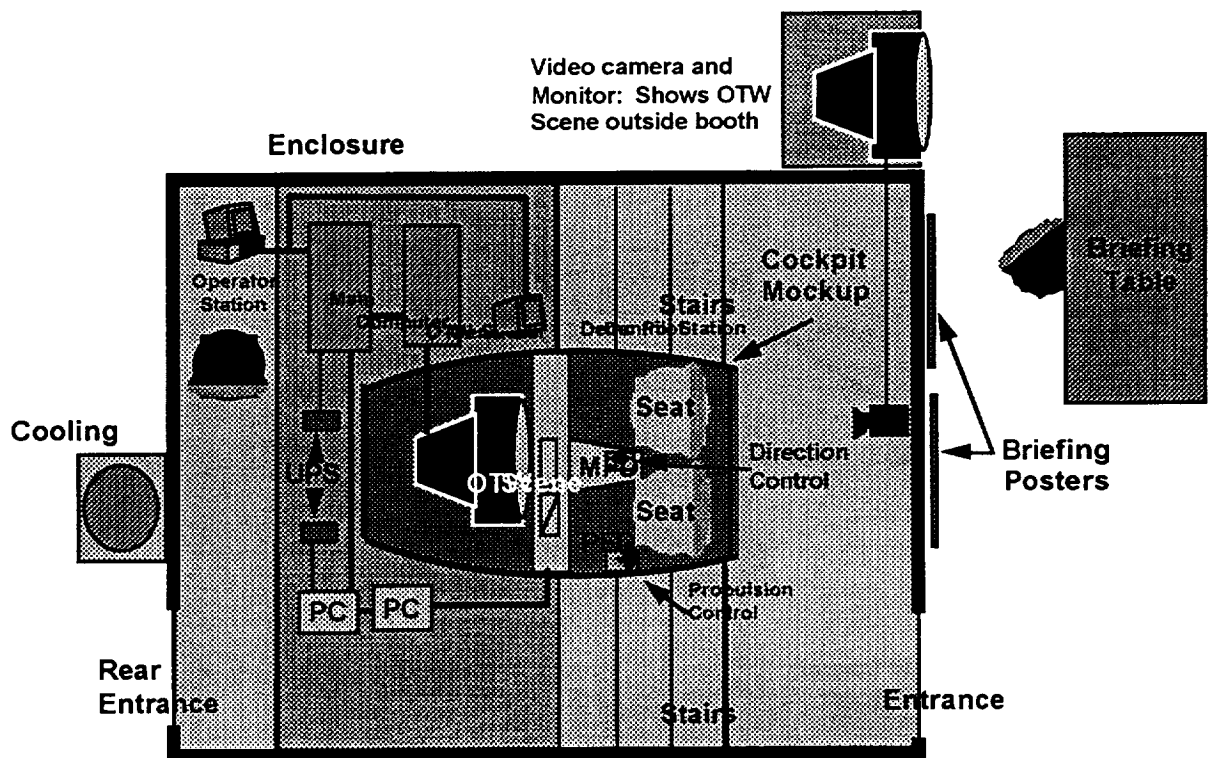


## 4. DESIGN

### 4.1 STRUCTURAL DESIGN

The basic layout of the physical structure is depicted below.

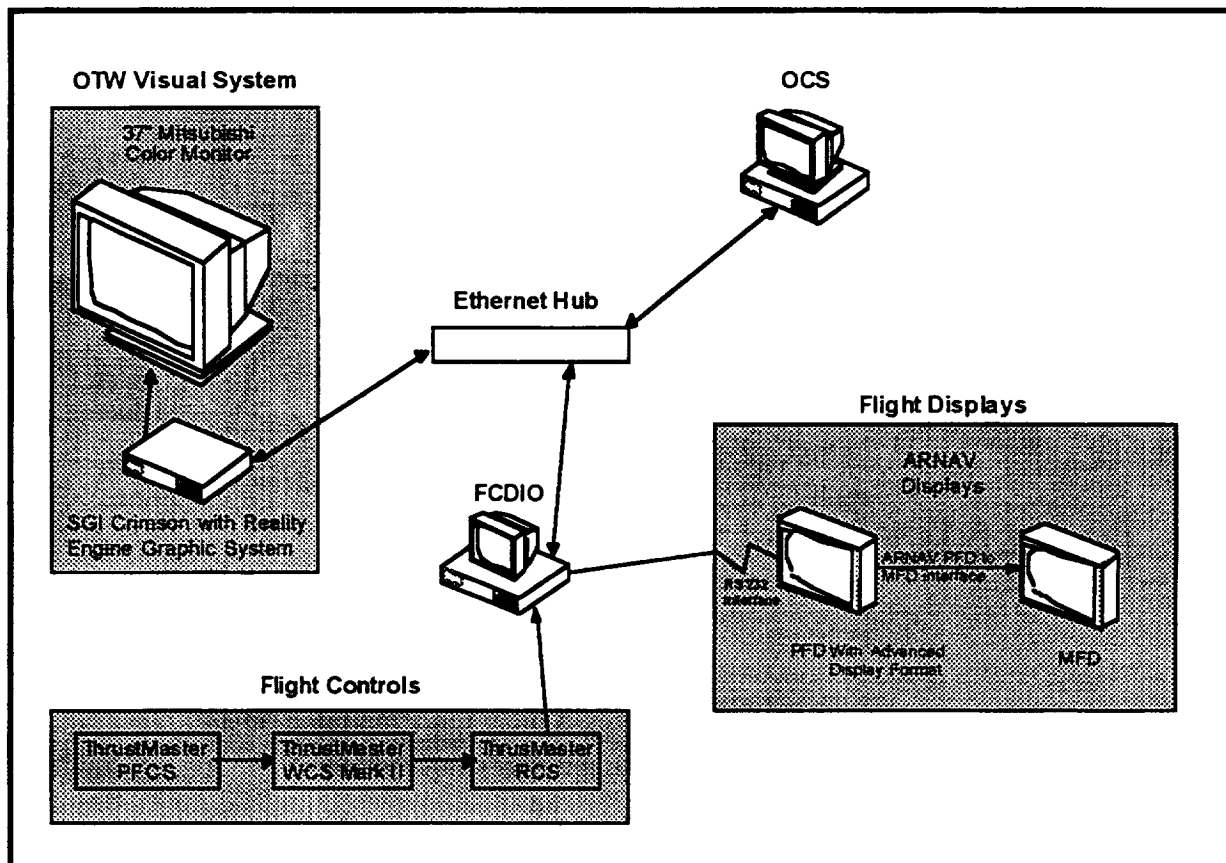
Figure 2. Structural Design Layout



## 4.2 COMPUTER SYSTEM ARCHITECTURE

The following sections describe the major components and primary interfaces for the computer system architecture of the ACD as shown in Figure 1.

Figure 3. ACD Computer System Architecture



#### 4.2.1 Major Components

The computer system architecture consists of six major components identified and described in Table 1.

**Table 1 ACD Computer System Architecture Components**

Component Name	Configuration	Functionality
Operator Control Station (OCS)	<ul style="list-style-type: none"><li>• SGI Indigo<sup>2</sup> XL with:<ul style="list-style-type: none"><li>a) 17" Color Monitor</li><li>b) IRIX 5.3</li><li>c) CTA Simulation Systems MSS</li></ul></li></ul>	Simulation control, flight modeling, scenario generation, and data recording
Out-The-Window (OTW) Visual System	<ul style="list-style-type: none"><li>• Silicon Graphics Crimson with Reality Engine Graphics System</li><li>• Mitsubishi color monitor</li></ul>	Displays out-the-window visual scenes
Flight Controls and Displays I/O (FCDIO) System	<ul style="list-style-type: none"><li>• 486 PC with<ul style="list-style-type: none"><li>a) 8 MB RAM</li><li>b) 500 MB hard drive</li><li>c) 3COM Ethernet card</li><li>d) 15" color monitor</li><li>e) ThrustMaster ACM Game Card</li><li>f) FreeBSD UNIX</li></ul></li></ul>	Routes input from the Flight Controls to the OCS; Routes output from the OCS to the Flight Displays
Flight Controls	<ul style="list-style-type: none"><li>• ThrustMaster Pro Flight Control System</li><li>• ThrustMaster Weapons Control System Mark II</li><li>• ThrustMaster Rudder Control System</li></ul>	Acts as demonstrator control stick Acts as demonstrator SLPC  TBD
Flight Displays	<ul style="list-style-type: none"><li>• Two ARNAV Display Systems<ul style="list-style-type: none"><li>a) PFD Modified with Paver Concept</li><li>b) MFD with ARNAV Panel 2000 Format</li></ul></li></ul>	Serve as the PFD and MFD for the demonstrator
Ethernet Hub	<ul style="list-style-type: none"><li>• 4-port 10BaseT Ethernet mini-hub</li></ul>	Provides connectivity for the OCS, OTW Scene Generator, and FCDIO

The OCS acts as the controlling element of the ACD. It communicates with the other components via a 10BaseT twisted pair Ethernet cable. An SGI Indigo<sup>2</sup> XL hosts CTA Simulation Systems Mission Simulator System (MSS) software. MSS provides simulation control, flight modeling, scenario generation, and data recording for the ACD. A 19" color monitor is used for the OCS display.

The OTW Visual System is composed of a Silicon Graphics Crimson computer with the Reality Engine graphics system which provides the visual scenes displayed on a

37" Mitsubishi color monitor. This component is connected to the other components of the architecture via a 10BaseT twisted pair Ethernet cable.

The FCDIO System accepts inputs from the Flight Controls and provides outputs to the Flight Displays. It is a 486 PC running the FreeBSD UNIX operating system. The PC is configured with a ThrustMaster ACM Game Card that is connected to the Flight Controls. A driver residing on the FCDIO accepts these inputs and translates them into Ethernet packets for transmission to the OCS. Another driver accepts flight display Ethernet packets from the OCS that are translated into RS-232 packets for transmission to the Flight Displays.

The Flight Controls include the following.

1. ThrustMaster Weapons Control System (WCS) Mark II - This element acts as SLPC.
2. ThrustMaster Pro Flight Control System (PFCS) - This element provides a joystick-like control which replaces the control wheel and column of normal aircraft.
3. ThrustMaster Rudder Control System (RCS) - It has not yet been determined that rudder pedals are needed in the concept demonstrator. For the time being, the rudder pedals will provide yaw control for the simulator.

Two ARNAV LCD cockpit display units are used for the Primary and Multifunction Flight Displays. A single RS-232 interface is used to transmit packets from the FCDIO System to the first ARNAV display system which acts as the PFD. This unit passes along the information needed to the second ARNAV display system which acts as the MFD.

The Ethernet Hub provides connectivity for the OCS, OTW Visual System, and FCDIO System. It is a 10BaseT Ethernet hub containing a minimum of four ports.

#### **4.2.2 Primary Interfaces**

There are five primary interfaces identified and described as follows.

1. OCS-to-Ethernet Hub — The OCS is connected to the Ethernet Hub via a 10BaseT twisted pair Ethernet cable. This allows for the OCS to send position and rate information to the OTW Visual System and the FCDIO. It also is used to accept control inputs from the simulator user from the FCDIO.
2. OTW Visual System-to-Ethernet Hub — The OTW Visual System is connected to the Ethernet Hub via a 10BaseT twisted pair Ethernet cable. It accepts position and rate information from the OCS through this interface.

3. FCDIO-to-Ethernet Hub — The FCDIO is connected to the Ethernet Hub via a 10BaseT twisted pair Ethernet cable. This allows for the Flight Control inputs to be sent to the OCS. The FCDIO also accepts Flight Display information from the OCS over the Ethernet. The protocol for this interface is a tailored MSS Remote Message Interface.
4. FCDIO-to-Flight Displays — The FCDIO is connected to the ARNAV display system that acts as the PFD through the COM1 port. This port is configured as an RS-232 interface with a DB-9 male connector. The ARNAV display systems wiring harness plugs directly into this connector. Refer to the ARNAV AHRS Interface Control Document for the definition of the communication parameters and data record format of the information sent to the Flight Displays.
5. FCDIO-to-Flight Controls — The FCDIO is configured with a ThrustMaster ACM Game Card that accepts inputs from the suite of ThrustMaster controls identified in the Primary Components section above. As shown in Figure 2, these controls are daisy-chained together to the game card port. In addition, the WCS Mark II is connected in line with the keyboard of the FCDIO PC (not shown in Figure 2).

### 4.3 PILOT DISPLAY FORMAT (FORMAT/HW/SW)

#### 4.3.1 Primary Flight Display (PFD)

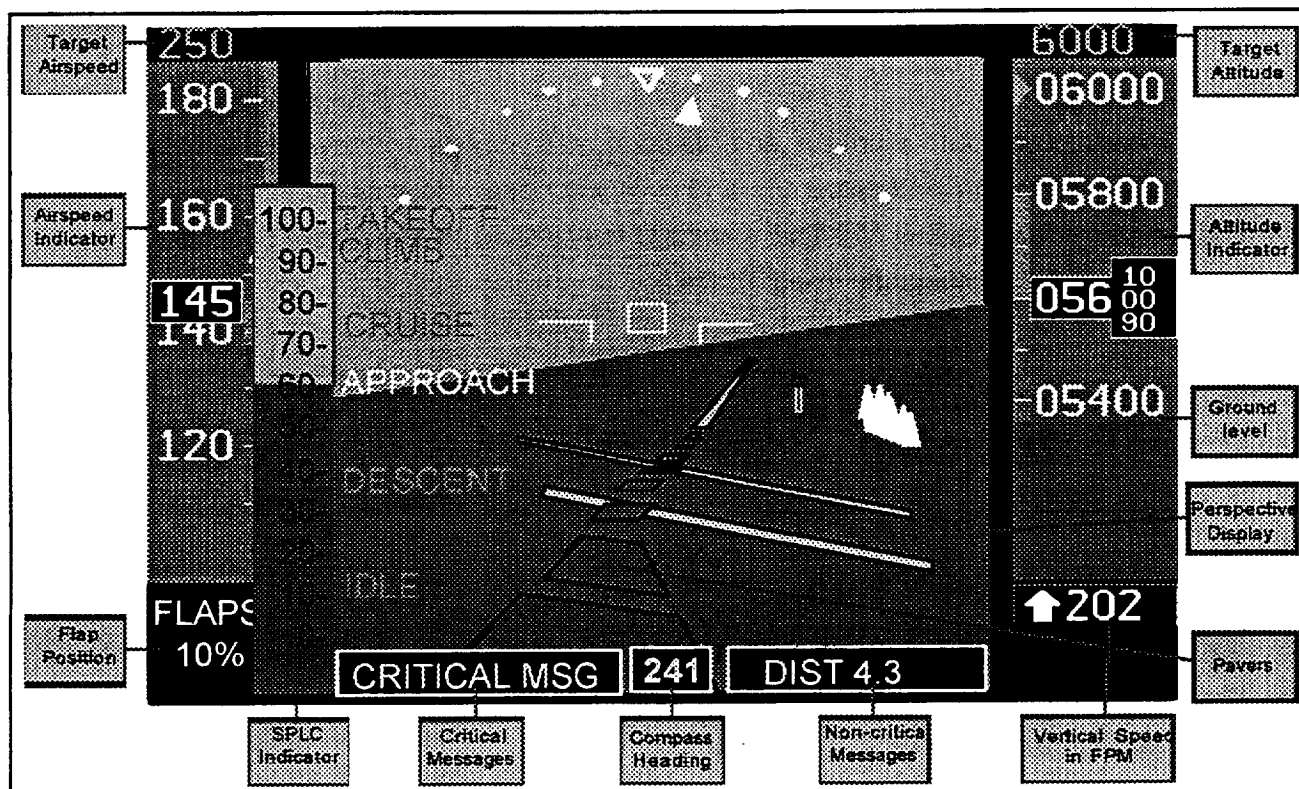


Figure 4. Primary Flight Display Format

The Primary Flight Display (PFD) is an integrated electronic flight instrument display intended to provide the pilot with enhanced situational awareness.

The PFD is located in the pilot's primary field of view. The central window on the display provides a conformal perspective representation of primary visual landmarks in the pilot's forward field of view and flight path information in a simulated three-dimensional, perspective format consisting of a series of rectangular "paver blocks" suspended along the desired flight path. This format is intended to supply sufficient information for control of the aircraft along the desired flight path and to provide the pilot the ability to fulfill the requirements of a three or four dimensional flight plan.

The *left vertical* section of the display is used for *speed management*.

The *right section* of the display is used for *altitude management*.

The PFD incorporates both a critical and non-critical message window. Examples of critical messages are ground proximity and stall warnings. Non-critical messages are altitude countdown below 300 feet and ATC messages. A *de-clutter function* enhances the ability to efficiently interpret data.

The PFD data is collected by the:

- Attitude Heading Reference System (AHRS)

- Digital Air Data System (DADS)

- Navigation Management System (NMS)

The data collected from each subsystem is available through the *communications bus* for display on the PFD.

#### **4.3.1.1 SYMBOLOGY**

PFD symbology is described as follows:

**Ground Proximity Indication** is integrated onto the altitude display. A **GROUND PROX** alert is given in the critical message window if the requirements for a ground proximity alert are fulfilled. The elevation data is currently derived from U.S. Geological Survey Elevation Mapping coordinates, but in the future it will include 1 meter and 10 meter data from the Defense Mapping Agency Landsat program.

**Critical Message Window** displays messages that require immediate attention by the pilot. Examples include over/under speed based upon flight control configuration, Ground Proximity, stall warning, altitude deviations that will violate hard limit restrictions, failure of other systems, and any other aircraft state vector or configuration, or air traffic information that convey urgency to the pilot.

**Non-Critical Message Window** is used for display of information that is of interest to the pilot, but does not require action or response from the pilot. Examples include altitude countdown when less than 300 feet AGL, and system status reports.

**V Speeds and Speed Ranges** are shown on the airspeed tape. Any change in flight dynamics (weight, speed, AOA, etc.) will adjust the V - Speeds. This "one stop" portion of the display eliminates "read-interpret-integrate-decide" procedure (measured at a minimum of three seconds by a proficient instrument pilot) necessary with conventional and widely spaced "T" instruments. The display permits the pilot to look and comprehend without extensive delay.

**The SPLC and Power Management** is shown in a temporary window that appears on the right edge of the left airspeed management window and the left edge of the central window. When the SPLC is moved the power indicator tape appears and the various power "detents" appear with the descriptive word just to the right of the power indicator tape. The present position of the SPLC is indicated by motion of the colored portion of the power indicator tape with the top edge of the tape indicating the power position. When the top of the colored bar on the tape reaches a detent setting, the word representing that setting changes to a white "highlight" setting to indicate that the SPLC functions associated with that setting are activated. In the example above, the

SPLC is set at the APPROACH detent position indicating that the SPLC has just been moved to the APPROACH detent. The system will now properly configure the powerplant for optimum operation in the APPROACH mode, adjusting power to maintain approach speeds and other parameters. If the SPLC is not moved for 10 seconds the SPLC Power Management window will disappear until the SPLC is moved again.

#### 4.3.2 Multi-Function Display (MFD)



Figure 5. MFD Navigation display

The MFD is an integrated electronic flight instrument display designed to provide the pilot with enhanced situational awareness.

The MFD is located in the pilot's primary field of view and is to the right of the Primary Flight Display (PFD). It presents graphic information about airports, nav aids, airways, obstacles, airspace boundaries, and other geographic features. It utilizes a North-up



or Track-Up moving map display. It also provides a checklist display for all phases of flight and an interface to the Flight Management System (FMS).

The MFD incorporates many functions which are selected through a system of menus and submenus. The MFD provides control of the scale and configuration of the moving map. A de-clutter function enhances the ability to interpret data.

The MFD also incorporates the Radio Management System (RMS) which enables the pilot to tune his VHF Nav/Com radios through the MFD.

The MFD provides these displays;

- Graphical Display of airports, nav aids, airways,

- Obstacles, and other geographical features

- Checklist Display and Validation for all phases of flight

- Radio Management System (RMS)

- Radar Control Unit (RCU)

- Interface to Flight Management System (FMS)

#### **4.3.2.1 Engine Indication Crew Advisory System (EICAS)**

The EICAS system displays all phases of powerplant operation. The EICAS system monitors up to 35 engine and airframe parameters through imbedded sensors and transducers. The sensor sample rate is *10 times per second* so that changes are displayed instantaneously.

The heart of the EICAS system is the data acquisition computer that converts the various types of sensor data into a digital format, does appropriate filtering and data conversion, then sends the data to the EICAS screen for display and monitoring. If desired, two data acquisition computers can be installed to increase the number of sensors monitored to 70.

The display is user-definable and can display reciprocating or turbine engine parameters.

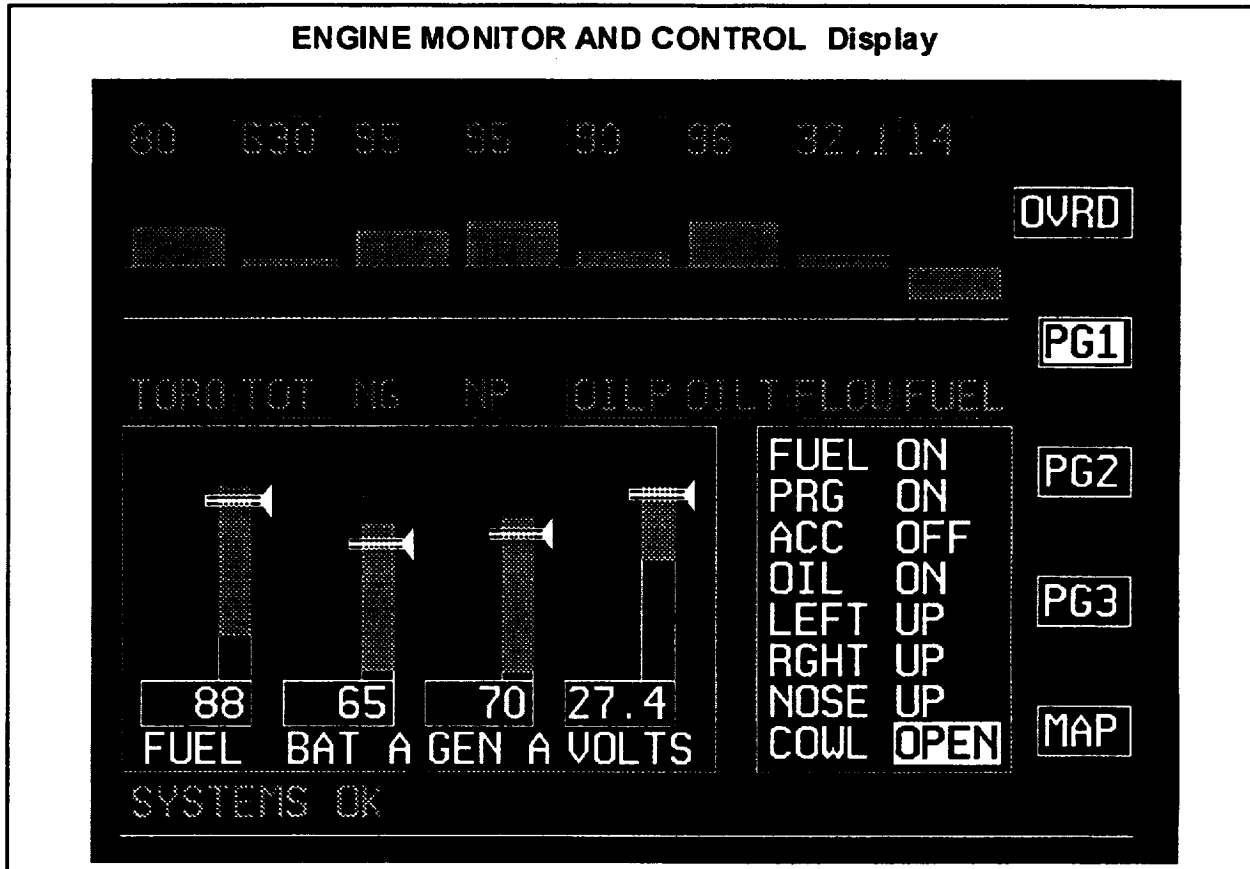


Figure 6. EMACS Display Page

#### EMACS

EICAS display uses NASA LaRC developed E-MACS (Engine Monitoring and Control System).

During flight, the E-MACS memorizes the performance of the aircraft and “learns” to predict subsequent enroute performance. When an out-of-range event occurs, the EICAS warns the pilot by flashing a CAUTION identifying the problem and lighting the appropriate annunciator.

If conditions are within normal ranges, the EICAS display can be suppressed or the EICAS display can be "windowed" onto the MFD, allowing the pilot to see both engine and airframe parameters and the moving map display.

For the purposes of the Concept Demonstrator at Oshkosh '96 the EMACS and EICASS will be a static presentation. Future Concept Demonstrator displays may include functional EICASS and EMACS.

#### **4.4 OUT THE WINDOW SCENE (FORMAT/HW/SW)**

The out-the-window scene is displayed on a 37" Mitsubishi color monitor mounted above and behind the PFD and MFD displays to provide realistic visual cues for flight. The out the window scene is a full three dimensional representation of the DEN airport and the surrounding terrain in which motion is simulated and synchronized with the concept demonstrator control inputs to the extent necessary to fulfill the needs of the concept demonstrator scenario provided in this document. The out-the-window scene is

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13. ABSTRACT (Maximum 200 words)  An AGATE Concepts Demonstration was conducted at the Annual Aircraft Owners and Pilots Association (AOPA) Convention in 1996. The demonstration consisted of an interactive simulation of a single-pilot, single-engine aircraft in which the participant took off, flew a brief enroute segment and then flew a Global Positioning System (GPS) approach and landing. The participant was provided an advanced "pathway-in-the-sky" presentation on both a head-up display and a head-down display to follow throughout the flight. A single lever power control and display concept was also provided for control of the engine throughout the flight. A second head-down, multifunction display in the instrument panel provided a moving map display for navigation purposes and monitoring of the status of the aircraft's systems. An estimated 352 people observed or participated in the demonstration, and 144 surveys were collected. The pilot ratings of the participants ranged from student to Air Transport Rating with an average of 1850 hours total flight time. The performance of the participants was surprisingly good, considering the minimal training in a completely new system concept. The overwhelming response was that technologies that simplify piloting tasks are enthusiastically welcomed by pilots of all experience levels. The increase in situation awareness and reduction in pilot workload were universally accepted and lauded as steps in the right direction.				
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